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MECHANICAL APPLICATION OF FERTILIZERS TO COTTON IN SOUTH CAROLINA, 1931 [1]

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INTRODUCTION

The study of the mechanical application of fertilizers to cotton has been in progress in South Carolina for three years. Progress reports have been published on the 1929 [2] and 1930 [3] work. During 1929, 22 representative fertilizer distributors were tested in both the field and laboratory. The field tests were made on two widely different types of soil.

In 1930 experiments were conducted on three soil types. The influences of the following factors on the germination and yield of the cotton were studied: Placement of the fertilizer with respect to the seed; rate of application; irregularity of distribution; and particle size of the fertilizer. A special machine which simultaneously planted the seed and applied the fertilizer was used in order to insure the most uniform conditions possible throughout the experiments.

These experiments were continued cooperatively during 1931 by the Clemson Agricultural College and Experiment Station, the National

[1] The authors are indebted to E. E. Hall, J. A. Riley, and C. S. Patrick, of the Pee Dee, Sand Hill, and Clemson College Agricultural Experiment Stations, respectively, for assistance in connection with the field work; to F. R. Reid, of the Bureau of Chemistry and Soils, for assistance in making the pot tests, and to A. L. Sharp, of the Bureau of Agricultural Engineering, for assistance in applying the fertilizers.

[2] Cumings, G. A., Mehring, A. L., and Sachs, W. H. Field and laboratory studies of fertilizer distributors for cotton. Agr. Engin. 11: 149–160. 1930.

[3] ———. Serviss, G. H., and Sachs, W. H. Progress report on mechanical application of fertilizers to cotton in South Carolina, 1930. U. S. Dept. Agr. Circ. 192, 32 p., illus. 1931.

Fertilizer Association, and the Bureaus of Chemistry and Soils and of Agricultural Engineering of the United States Department of Agriculture. The test plots were located in South Carolina at the Pee Dee Experiment Station, Florence, on Norfolk very fine sandy loam; at the Sand Hill Experiment Station, Columbia, on Norfolk coarse sand; and at Clemson College, on Cecil sandy clay loam. The purpose of the study was to obtain further fundamental information which would serve as a basis for the development of more efficient distributing machines and the recommendation for more effective and safer methods of applying fertilizer to cotton at planting time.

MATERIALS AND METHODS

FERTILIZERS

Standard commercial fertilizers were used in these experiments. The nitrogen was derived one-fourth from organic sources and three-fourths from ammonium compounds, and the potash from muriate. The results of chemical analyses and drillability measurements made on those mixtures are presented in Table 1. Analysis formulas wherever used in this report refer to percentages of NH_3, P_2O_5, and K_2O in the order named.

TABLE 1.—*Chemical analyses*[1] *and drillability measurements of the fertilizers*

Analysis formula	Total N as NH_3	Actual NH_3	Total P_2O_5	Available P_2O_5	K_2O	H_2O	Apparent specific gravity	Angle of repose
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Grams per cubic centimeter*	*Degrees*
4–8–4	3.98	3.12	9.67	7.57	4.28	3.06	1.03	39.5
8–16–8	7.93	5.94	17.87	17.63	8.32	3.83	.87	37.5

[1] Made by L. M. White, Junior Chemist, Bureau of Chemistry and Soils.

SEED

Coker's Super Seven cottonseed of high germination were used in the tests at the Pee Dee and Sand Hill stations. Dixie Triumph seed of high germination were used at Clemson College. All seed were delinted with sulphuric acid. In all cases the seed were planted at the rate of approximately 1 bushel per acre.

FERTILIZER PLACEMENTS

Twenty-six different placements of the fertilizer with respect to the seed or plant were used on the Norfolk very fine sandy loam, the largest number employed at any station. The total fertilizer application at planting time was made in 24 positions, and the application of a part of the fertilizer after thinning introduced the two additional placements. The number of placements used on the other soils differed somewhat according to the amount of land available. Descriptions of the placements are given in the tables of results.

Supplementary tests were made in which the coverage of the seed and the treatment of the soil about the seed differed from those of the comparable standard tests.

EXPERIMENTAL MACHINE AND EQUIPMENT

A special combination planter and fertilizer distributor was built particularly to meet the requirements of this experimental work which necessitates a machine having greater accuracy, more equipment, and wider ranges of adjustments than might seem feasible or necessary for commercial machines. The general design of the machine is shown in Figure 1.

The soil-working tools are mounted on a subframe which can be adjusted vertically without change of inclination. Thus the whole assembly can be raised or lowered as required without affecting the relative placements of fertilizer and seed. The subframe equipped for normal operation in placing the fertilizer in a band below the seed is shown in Figure 2. All soil-working tools except the press wheel are held rigidly to the frame. The shovel, *a*, has wings attached for

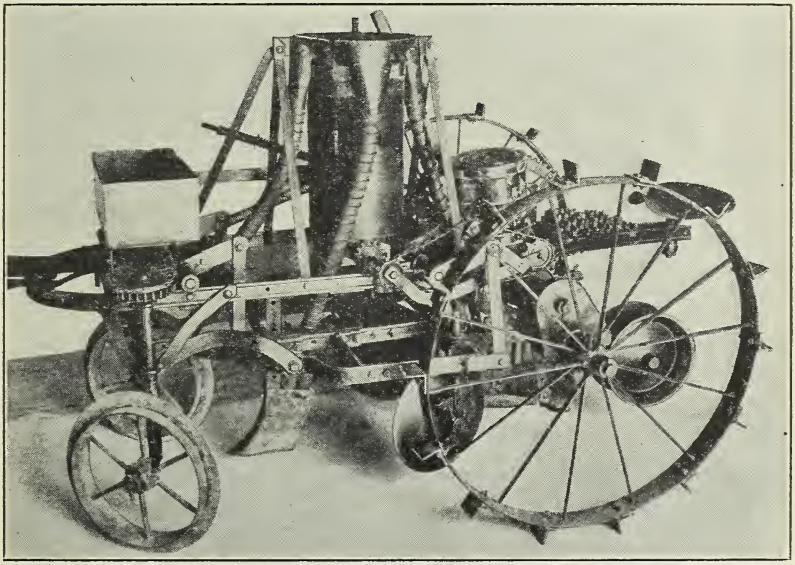

FIGURE 1.—Special combination planter and fertilizer distributor built under general specifications of the Bureau of Agricultural Engineering

excluding the soil until the fertilizer has been deposited in the furrow, in order to maintain a constant width and placement of the fertilizer band. The purpose of the bedding disks, *b*, is to cover the fertilizer and throw an excess of soil in front of the seed shoe, *c*. Thus any depressions are filled, which permits a constant relative height of the seed with respect to the fertilizer as well as uniform covering of the seed. The lateral wings, *d*, attached to the seed shoe, lower the seed bed to a constant height and thus not only regulate the depth but also insure a uniform depth of planting. The press wheel, *e*, is of the open type and is free to exert constant pressure for covering the seed and for firming the soil.

Figure 3 shows the manner of attaching and adjusting, both vertically and laterally, a pair of single-disk furrow openers, *a*, for placing the fertilizer in narrow bands at the sides of the seed. The soil lying between the disks in which the seed are planted is not disturbed in

normal operation. In certain tests, however, it seemed desirable to make comparisons of seed planted in disturbed and undisturbed soil.

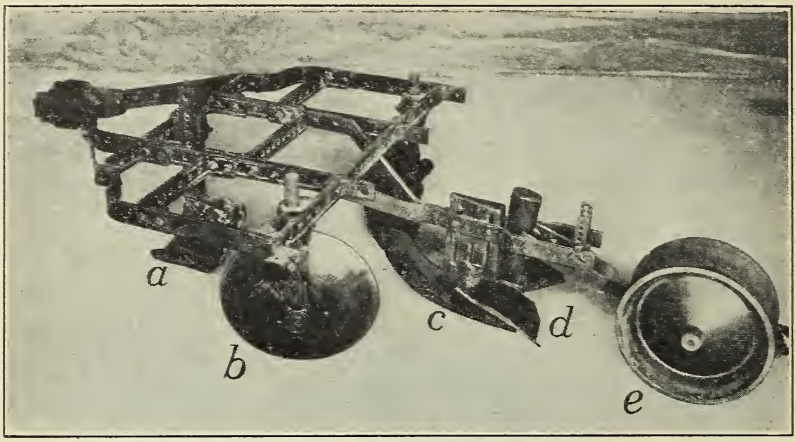

FIGURE 2.—Tool frame equipped for normal operation with furrowing shovel attached, to place the fertilizer in a band below the seed: *a*, Furrowing shovel for placing the fertilizer; *b*, bedding disks; *c*, seed shoe; *d*, adjustable wings to regulate depth of planting; *e*, press (covering) wheel

In this case, the shovel, *b*, was attached to stir the soil in which the seed were planted.

Figure 4 shows the tools used for mixing the fertilizer with the soil below the seed. The fertilizer is first deposited in a furrow 4 inches

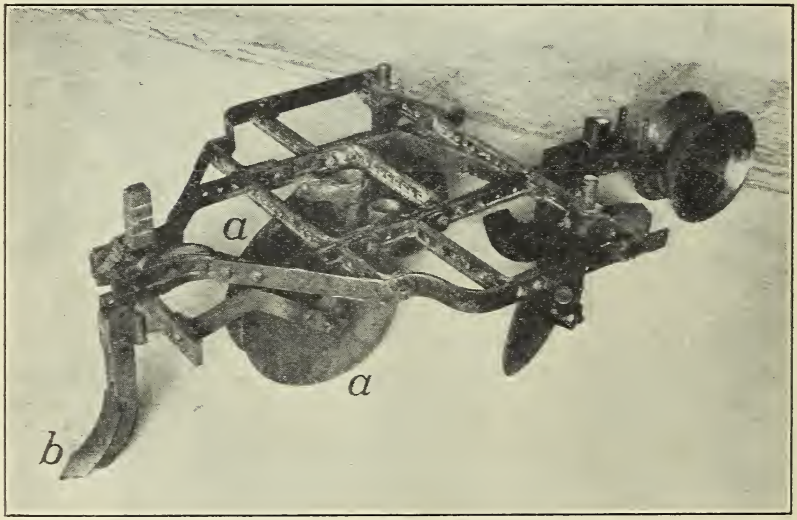

FIGURE 3.—Mounting on tool frame of single-disk furrow openers with both lateral and vertical adjustment for placing the fertilizer in bands at each side of the seed: *a*, Single-disk furrow opener, *b*, stirring shovel

wide, opened by the shovel, *a*. The two small shovels, *b* and *c*, each in turn lift certain quantities of the fertilizer and soil and mix them to a considerable extent. Fertilizer is not readily mixed with the damp soil. For that reason thorough mixing, as usually conceived,

could probably not be obtained by any simple arrangement on a combined planter and distributor.

For placing all or a part of the fertilizer in contact with the seed a delivery tube was attached at the rear of the seed shoe.

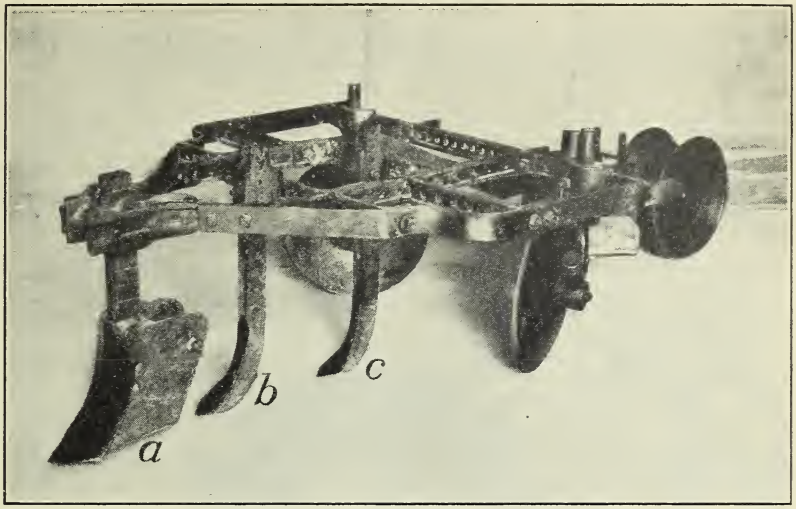

FIGURE 4.—Arrangement of shovels on tool frame for mixing the fertilizer with the soil below the seed: *a*, Shovel for opening furrow in which fertilizer is deposited; *b* and *c*, mixing shovels

A small press wheel, *a*, attached at the rear of the seed shoe as shown in Figure 5 was used in certain tests to press the seed into the furrow. Blade coverers, *b*, then covered the seed with loose soil. For

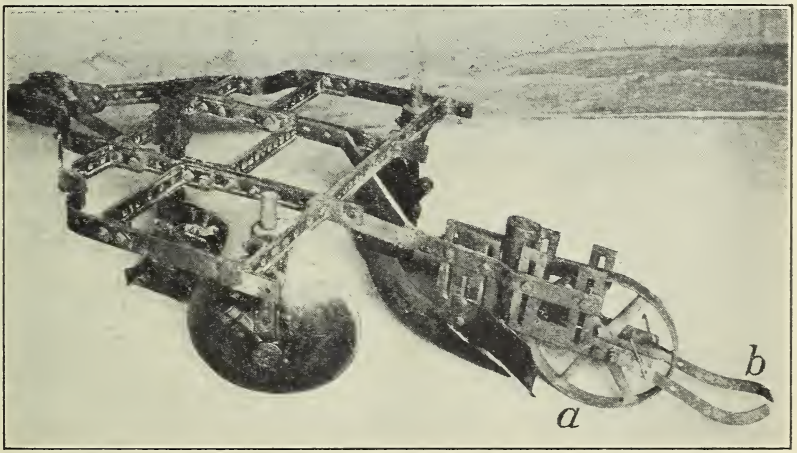

FIGURE 5.—Press wheel and blade coverers attached at rear of seed shoe for pressing seed to desired depth and covering with loose soil: *a*, Press wheel, diameter 10 inches, width of tire 1.25 inches; *b*, blade coverers

example, when the depth of planting is 1 inch the seed are first deposited in a very shallow furrow and pressed about 0.75 inch further into the soil. This arrangement aids in establishing capillarity below the seed and reduces the formation of crust above the seed.

The fertilizer-dispensing mechanism is of the revolving-cylinder top-delivery type. The plunger rises a definite distance for each revolution of the drive wheel and thus dispenses the fertilizer at a constant rate. For a particular soil type, variation in the slippage of the drive wheels which would give a corresponding variation in the delivery rate has been found to be negligible when the seed bed is well prepared. The average percentage of wheel slippage recorded for each soil type is as follows: Very fine sandy loam, 13.4 ± 0.5; coarse sand, 13.7 ± 0.01; sandy clay loam, 12.4 ± 0.03. The only possibility for material variation in the application rate is in compacting the fertilizer in the hopper during operation. By thoroughly settling the fertilizer in the hopper before the operation started, a practically constant delivery rate was obtained. By first determining the weight of fertilizer held by the hopper and the number of revolutions of the

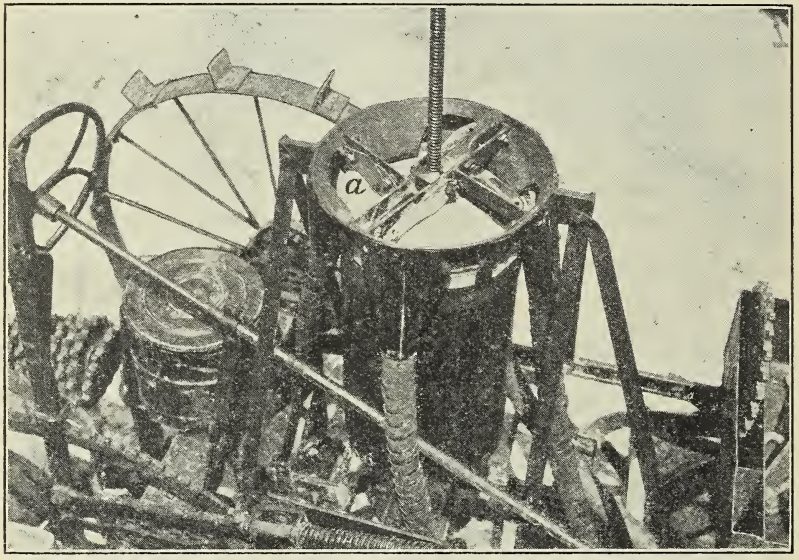

FIGURE 6.—Fertilizer-hopper head with four delivery openings and adjustable delivery blades: *a*, Delivery blade with slot adjustment at outer end

drivewheel for any known distance under the field conditions, delivery-rate adjustments can be determined mathematically since the dispensing action is positive.

The hopper has been provided with four delivery openings and tubes. In those tests where a part of the fertilizer was placed in contact with the seed and the remainder at both sides of the seed, three delivery tubes were required. The delivery rate through any tube can be positively controlled by the adjustable delivery blades, *a*, as shown in Figure 6. By adjustment of the delivery blades the whole delivery can be diverted into one tube or in any desired fractional parts into two or more tubes.

No rate of application differed more than about 1 per cent from that desired. The variation in rate of application among the six rows of individual tests was approximately the same for all fertilizers, the average deviation being 0.2 per cent.

The fertilizers were distributed along the row with a high degree of uniformity. The average coefficient of variation as determined by the method described in a previous report [4] was 8.8 per cent, on the basis of 1-foot intervals.

LAYOUT OF THE EXPERIMENTS

The project was primarily a study of fertilizer placement, although the use of single and double strength fertilizers in the placement tests affords a comparison of the two materials. Determinations were made on the movement and concentration of salts in the soil. The criteria upon which relative efficiencies were based are concentration of salts in the root zone, germination, and yield.

The tests were arranged in series, each series representing all of the various treatments as to placement or rate of application of fertilizer. The rows were 124.5 feet long and were spaced 3.5 feet apart. Observations were made on two 50-foot lengths in each row, 12¼ feet at each end being discarded. Six identical series were planted at the Pee Dee station on very fine sandy loam, six at the Sand Hill station on coarse sand, and five at Clemson College on sandy clay loam. Thus each result obtained at the Pee Dee or Sand Hill station represents an average of 12 observations, while each one at Clemson College represents an average of 10 observations.

The order of the tests was arranged to avoid extreme differences in final stand of adjacent rows. Thus, significant differences in plant competition were largely eliminated.

Five unfertilized checks were equally spaced throughout each series. The soil about the seed was not disturbed to the same degree in obtaining the various fertilizer placements, and if a different rate of germination occurred with seed planted in firm soil from that when they were planted in disturbed soil this fact might account, in part, for the differences among fertilizer placements, particularly with respect to germination. Hence different furrowing tools were used in each check, corresponding to those used on representative placement tests. The soil treatment for each check is given in Table 4.

The unfertilized checks were arranged in such a manner that they did not lie adjacent to the same tests throughout the series of replicate plats. An unfertilized check was adjacent to only one plat of each test. The following example of 36 tests shows the location of checks X, Y, and Z:

		X	Y	Z
For series A	Between tests	1 and 2	13 and 14	25 and 26
For series B	Between tests	3 and 4	15 and 16	27 and 28
For series C	Between tests	5 and 6	17 and 18	29 and 30
For series D	Between tests	7 and 8	19 and 20	31 and 32
For series E	Between tests	9 and 10	21 and 22	33 and 34
For series F	Between tests	11 and 12	23 and 24	35 and 36

This arrangement placed all tests on the same basis in regard to proximity to unfertilized rows.

[4] CUMINGS, G. A., MEHRING, A. L., SERVISS, G. H., and SACHS, W. H. PROGRESS REPORTS ON MECHANICAL APPLICATION OF FERTILIZERS TO COTTON IN SOUTH CAROLINA, 1930. U. S. Dept. Agr. Circ. 192, 32 p., illus. 1931.

SOIL MOISTURE AND RAINFALL

Soil moisture and rainfall are given in Tables 2 and 3. Daily rainfall records are shown only for periods in which rainfall had an important bearing on the experiments. The total rainfall for the period of the experiment is below normal at each station. The rainfall during May, which largely includes the germination period, was considerably above normal, but during June and September was exceptionally low.

TABLE 2.—*Daily rainfall and soil moisture during periods of soil observations, 1931*

Date	Norfolk very fine sandy loam (Pee Dee station)		Norfolk coarse sand (Sand Hill station)		Cecil sandy clay loam (Clemson College station)	
	Rainfall	Soil moisture	Rainfall	Soil moisture	Rainfall	Soil moisture
	Inches	*Per cent*	*Inches*	*Per cent*	*Inches*	*Per cent*
Apr. 1	0.22		0.88		0.50	
Apr. 4					1.45	
Apr. 5	.80		.92			
Apr. 6	.35		.18		.33	
Apr. 11					.45	
Apr. 16		9.03				
Apr. 18		8.83			.11	
Apr. 20	.30	11.42	1.27		.29	
Apr. 21		9.46				
Apr. 22	.18		.30		1.96	
Apr. 23	.38			5.36		
Apr. 25				4.91	.04	
Apr. 26		8.93			.07	
Apr. 27	.28		.28	5.06		
Apr. 28				4.98		
Apr. 30		7.17			(1)	
May 1		7.39			.90	12.41
May 2	.41	11.26	.33		2.80	
May 3	.28			4.87		
May 4			.13			
May 5				4.81	1.90	
May 6			.18	5.38	.76	
May 7	.47		.05		1.34	
May 8	1.20		.23			
May 9					.41	11.34
May 10	.81		.38	5.40		
May 11					.60	
May 12	.20		.84	7.48		
May 13	.10			4.73		11.06
May 16					.02	8.26
May 17					.02	
May 18				3.09		
May 19		8.79				
May 20				4.46	.22	
May 21	.50		.91		.45	
May 22	.48		1.03		.06	
May 23	1.20					
May 25			.05			7.89
May 26					.86	
May 27			.05			
May 28	.59		.13		.05	
Aug. 2					.08	
Aug. 4	.27	5.00				
Aug. 6	1.30	9.57			.12	
Aug. 7	.38		1.73		(1)	
Aug. 8	.05		1.47			
Aug. 10					.07	
Aug. 11					.40	
Aug. 12	1.05		.66	3.68	.23	
Aug. 13			.53		.27	
Aug. 14	.08					6.31

[1] Trace.

TABLE 3.—*Monthly rainfall during growing season*

Month	Norfolk very fine sandy loam (Pee Dee station)		Norfolk coarse sand (Sand Hill station)		Cecil sandy clay loam (Clemson College station)	
	Normal	1931	Normal	1931	Normal	1931
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
April	3.25	2.51	2.89	3.83	3.93	5.20
May	4.65	6.24	3.09	4.31	3.94	10.39
June	5.31	2.37	4.17	1.00	4.85	.37
July	5.69	5.83	5.35	5.19	5.27	2.64
August	3.79	6.38	5.47	5.33	5.00	1.88
September	5.11	.57	3.45	.71	4.10	1.50
Total	27.80	23.90	24.42	20.37	27.09	21.98

GERMINATION

Seed were planted on the very fine sandy loam of the Pee Dee station, having about 9 per cent moisture, on April 16 and 17. Good rains fell on April 20, 22, 23, and 27. On April 23, 0.38 inch of water fell in a dashing rain which greatly packed the soil. A number of plants were in the crook stage and most of these died. This rain was followed by a rather prolonged period of cold weather which materially delayed and injured germination. Furthermore, an exceptionally large number of the plants died before the last stand count just prior to thinning.

The 5.36 per cent moisture content of the coarse sand at time of planting on April 21 and 23 was favorable for the germination of the cottonseed. A good rain fell on April 27. Temperatures immediately after planting, possibly a little below normal, did not greatly retard germination.

The moisture content of the sandy clay loam at time of planting on May 1 was also favorable for germination. A 0.9-inch rain fell immediately after planting. A 2.8-inch rain fell the next day, and heavy rains followed on May 5, 6, and 7. The cool weather which accompanied the heavy rains slightly delayed germination. With 8 inches of rain falling during the week following planting, no injury to germination would be expected from fertilizer applied in any reasonable manner on this comparatively heavy soil.

The treatment of the soil about the seed differs among the unfertilized checks to correspond to the treatment for representative fertilized tests. The germination for the unfertilized tests as measured by the number of plants appearing above ground is given in Table 4. The results are rather inconsistent for the Norfolk very fine sandy loam, presumably because of the adverse weather and soil conditions during the germination period. For the coarse sand and sandy clay loam, stirring of the soil to a depth of 3 inches below the seed not only delayed germination but resulted in fewer plants appearing aboveground. There is some indication that planting the seed in Norfolk coarse sand, undisturbed to a distance of either 1.5 or 3.5 inches to each side, gave the most rapid germination and the largest number of plants.

TABLE 4.—*Number of cotton plants appearing aboveground per 50-foot row on unfertilized checks with different treatment of the seed bed, 1931*

Soil treatment	Norfolk very fine sandy loam; planted Apr. 16			
	Apr. 24	Apr. 29	May 6	May 19 [1]
Soil stirred 1.75 inches wide 2 inches below seed	9±2.0	171± 8.0	158± 6.7	113± 4.4
Do	5±1.2	220± 8.2	203±11.8	153± 9.7
Soil stirred 3.5 inches wide 3 inches below seed	[2] 0	[2] 155±16.0	[2] 192±20.2	[2] 140±15.3
Soil not stirred 1.5 inches to each side of seed	[2] 0	[2] 203±10.7	[2] 221±11.9	[2] 169±10.6
Soil not stirred 3.5 inches to each side of seed	11±2.2	179± 7.3	163± 8.0	126± 8.1
Average	5± .8	186± 5.1	187± 6.0	140± 4.9

Soil treatment	Norfolk coarse sand; planted Apr. 23			Cecil sandy clay loam; planted May 1		
	May 4	May 11	May 22	May 10	May 13	May 26
Soil stirred 1.75 inches wide 2 inches below seed	337±7.3	319± 7.7	264±10.4	168± 3.7	410± 5.1	462±7.1
Do	308±5.9	297±11.3	250±10.6	153±14.1	408± 6.2	460±8.7
Soil stirred 3.5 inches wide 3 inches below seed	[3] 268±7.6	241± 6.9	217± 6.1	123± 5.9	395±11.1	430±7.1
Soil not stirred 1.5 inches to each side of seed	354±7.8	345±10.6	276± 9.5	148± 8.6	429± 6.5	443±5.1
Soil not stirred 3.5 inches to each side of seed	305±7.2	308± 9.1	271±10.4	206± 3.8	433± 8.9	433±6.2
Average	314±4.1	302± 5.1	256± 4.7	160± 4.4	415± 3.9	446±3.4

[1] Final count includes only living plants.
[2] Planted Apr. 17.
[3] Planted Apr. 21.

EFFECT OF PLACEMENT OF FERTILIZERS

The germination as measured by the number of plants appearing aboveground, or comeup, is shown for various placements of 800 pounds per acre of 4–8–4 fertilizer in Table 5. The come-up counts on the very fine sandy loam and the coarse sand were of the same order, and striking differences will be noted among the tests. Serious injury to germination occurred on the sandy soils where the fertilizer was placed either in a 1.75-inch or 3.5-inch band at a depth of 3 inches or less below the seed, the damage being particularly serious where the fertilizer was placed 1 inch below the seed. No deterrent effects on germination were noticable with the fertlizer placed 4 inches below the seed.

TABLE 5.—*Number of cotton plants appearing aboveground per 50-foot row for various placements of 800 pounds per acre of 4–8–4 fertilizer, 1931*

Test No.	Fertilizer placement	Norfolk very fine sandy loam; planted Apr. 16				Norfolk coarse sand; planted Apr. 23			Cecil sandy clay loam; planted May 1		
		Apr. 24	Apr. 29	May 6	May 19 [1]	May 4	May 11	May 22 [1]	May 10	May 13	M 26 [1]
	No fertilizer [2]	5±0.8	186± 5.1	187± 6.0	140± 4.9	314± 4.1	302± 5.1	256± 4.7	160±4.4	415± 3.9	446± 3.4
	1.75-inch band:										
1	1 inch below seed	1± .2	13± 1.6	19± 3.7	3± .6	4± 1.4	9± 2.3	6± 1.5	97±6.6	392± 6.6	444± 6.2
2	2 inches below seed	13±1.1	147± 7.6	121± 8.6	13± 2.2	11± 3.1	33± 6.6	26± 5.4	157±5.2	409± 6.9	446± 4.0
3	3 inches below seed	22±3.2	182± 7.2	173±10.9	53± 7.0	176±12.4	244±10.8	190±10.4	170±5.1	384±10.3	463± 5.0
4	4 inches below seed	15±2.3	213± 9.2	215± 9.2	136± 7.2	359± 6.1	355± 7.7	294±11.7	[3]	----------	----------
5	2 inches below seed (seed pressed in furrow—covered with loose soil)	19±3.0	141± 7.9	109±11.4	14± 2.6	194±18.9	257±15.9	202±14.3	[3]	----------	----------
	3.5 inch band:										
6	1 inch below seed	0	11± 1.7	27± 3.1	5± 1.0	1± .3	4± 1.0	4± 1.3	142±6.2	402±13.9	450± 4.6
7	2 inches below seed	2± .4	118± 7.1	122± 7.7	37± 4.7	48± 5.4	126±11.8	106±10.7	171±4.5	421± 7.8	457±12.7
8	3 inches below seed	7±1.1	195± 6.2	171± 6.9	80± 7.4	124± 9.3	225±10.8	182±10.3	172±8.7	405± 4.6	446± 4.5
9	4 inches below seed	8±1.0	230± 6.6	201± 6.8	123± 7.1	316± 6.2	312± 7.4	270± 7.3	[3]	----------	----------
	Bands 1.5 inches to each side:										
10	1 inch below level of seed	12±1.5	224± 7.0	203± 9.3	99± 7.7	213±10.5	271± 6.8	170± 7.9	189±6.7	411± 6.8	447± 8.4
11	2 inches below level of seed	10± .9	238± 6.1	211± 8.5	135± 7.2	356± 7.8	345± 8.1	281± 6.8	200±9.4	406± 6.2	438± 5.8
12	3 inches below level of seed	7± .9	232± 5.8	210± 6.6	144± 6.9	348± 4.7	341± 6.4	289± 9.9	205±6.6	430± 5.3	464± 4.9
	Bands 3.5 inches to each side:										
13	1 inch below level of seed	5± .7	183± 6.3	174± 8.6	119± 9.6	278± 6.0	275± 6.1	235± 7.7	216±6.5	413± 8.2	453± 6.0
14	2 inches below level of seed	4± .6	172± 6.0	163± 7.9	115± 8.2	323± 7.3	294± 7.7	261± 8.7	211±7.9	427±10.1	456± 6.1
15	3 inches below level of seed	7± .9	194± 5.4	179± 5.1	121± 5.9	332± 3.6	312± 8.2	257± 9.8	198±9.1	399±14.4	432± 8.4
16	2 inches below level of seed (soil stirred below seed)	8±1.2	233± 7.0	209± 8.2	151± 9.6	345± 9.3	324± 8.1	287± 8.0	177±6.2	410±10.8	464± 3.8
17	2 inches below level of seed (seed pressed in furrow—covered with loose soil)	9±2.2	167± 6.1	168± 6.5	108± 6.4	355± 7.6	327± 9.5	269± 9.3	[3]	----------	----------
	One-eight of fertilizer in contact with seed:										
18	Seven-eighths in placement No. 2	0	5± 1.3	36± 4.3	6± .9	8± 1.8	41± 6.9	38± 5.0	[3]	----------	----------
19	Seven-eighths in placement No. 3	0	14± 2.7	84± 7.0	23± 2.1	58±14.3	171±17.1	141±14.2	2± .7	290±12.3	426± 5.0
20	Seven-eighths in placement No. 14	0	32± 7.1	115± 4.0	77± 3.2	66±13.2	182±14.0	158±13.9	6± .3	305±14.5	457± 5.5
	One-fourth of fertilizer in contact with seed:										
21	Three-fourths in placement No. 3	0	3± 1.3	35± 7.8	9± 3.0	3± .8	46± 4.8	56± 3.7	[3]	----------	----------
22	Three-fourths in placement No. 14	0	1± .4	36± 4.1	23± 2.0	5± 2.5	44± 8.3	45± 5.7	1± .1	221±16.7	383± 5.9
23	All fertilizer in contact with seed	0	0.2± .2	1± .2	2± .2	0± .1	4± 1.5	13± 2.6	0	2± .8	127± 4.8
24	Mixed with soil below seed	2± .3	141± 9.0	129±10.5	40± 6.4	12± 1.9	39± 3.9	34± 2.9	139±7.2	394± 6.9	437± 5.2
25	Band 1.5 inches to one side, 2 inches below level of seed	0	128±14.9	190±21.8	139±19.7	[3]	----------	----------	[3]	----------	----------
26	Band 3.5 inches to one side, 2 inches below level of seed	0	123±15.3	198±22.9	164±20.1	[3]	----------	----------	[3]	----------	----------
27	One-fourth of fertilizer on surface, three-fourths in placement No. 14	7± .5	196± 7.7	171± 8.4	113± 8.6	[3]	----------	----------	[3]	----------	----------

[1] Final counts include only living plants.

[2] Average of all checks.

[3] Tests were not conducted.

Comparison of tests 2 and 5, in which the soil below the seed had been stirred, shows no advantage of pressing the seed in the furrow and covering with loose soil on the very fine sandy loam where heavy rains fell immediately after planting; however, on the coarse sand compacting the soil on which the seed were planted was a distinct advantage.

On the sandy soils application of fertilizer in bands at the sides of the seed resulted in better germination than where it was applied in bands at the same depths directly below the seed. The stand and early growth of cotton where the fertilizer was applied in the Norfolk coarse sand at different depths directly below the seed and at the sides of the seed are shown in Figure 7. The poorest stand with placements at the sides of the seed was obtained where the fertilizer was applied in bands 1.5 inches to the sides and 1 inch below the level of the seed.

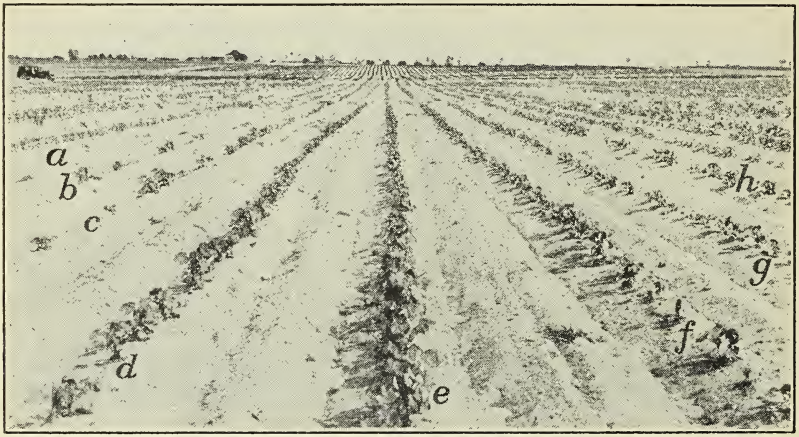

FIGURE 7.—Cotton planted April 23, photographed June 23 on Norfolk coarse sand, Columbia, S. C., 4-8-4 fertilizer applied at 800 pounds per acre in the following placements with respect to the seed: *a*, In contact; *b*, *c*, *d*, *e*, in bands 3.5 inches wide, respectively 1, 2, 3, and 4 inches below the seed; *f*, *g*, *h*, in a narrow band at each side, respectively 3, 2, and 1 inch below level of seed

Under the prevailing conditions, where the soil below the seed had not been stirred, pressing the seed in the furrow was of no advantage as may be seen by comparing tests 17 and 14.

Placing one-eighth or one-fourth of the application of 800 pounds per acre in contact with the seed and the remainder either in bands below or at the sides of the seed resulted in serious injury to stand on the sandy soils. Least injury occurred in these partial contact placements where one-eighth of the fertilizer was applied with the seed and the remainder in bands 3.5 inches to each side and 2 inches below the level of the seed. Placing the total fertilizer application in contact with the seed resulted in very serious injury.

Mixing the fertilizer with the soil below the seed as accomplished in these tests resulted in serious injury to germination and unsatisfactory stands.

On the sandy clay loam, good stands were secured with all placements used except where the fertilizer was applied in contact with the seed. A marked delay in germination occurred where one-eighth or one-fourth of the fertilizer was applied in contact with the seed and the

remainder either in bands at the sides of or in a band below the seed. Application of one-fourth, as compared to one-eighth, of the fertilizer in contact with the seed and the remainder in bands 3½ inches to the sides and 2 inches below the level of the seed resulted in the appearance of fewer plants aboveground, although the final stand was not seriously affected in either case.

EFFECT OF RATE OF APPLICATION OF FERTILIZER

On the sandy soils increasing the rate of application of 8–16–8 fertilizer from 200 to 400 and 600 pounds per acre, as shown in Table 6, resulted in a reduced number of plants appearing aboveground where it was applied in a 1.75-inch band 2 inches below the seed and where it was mixed with the soil. This is illustrated in Figure 8, A and B. Increasing the rate of application did not significantly affect the number of plants where the fertilizer was applied in bands at the sides of the seed. (Fig. 8, C.) At all rates of application the germination was materially improved by placing the fertilizer at the sides of the seed.

No serious effect on the stand resulted from applications of 8–16–8 fertilizer on the sandy clay loam at any rate or with any placement used, although there was a noticeable delay in germination and a slight reduction in number of plants where the fertilizer was mixed with the soil at the heavier rates.

SINGLE VERSUS DOUBLE-STRENGTH FERTILIZERS

A comparison of the results for placements 2, 14, and 24 (Table 5), where 800 pounds per acre of 4–8–4 fertilizer were used, with results of corresponding placements of 400 pounds per acre of 8-16-8 fertilizer in Table 6, shows no significant differences in the number of plants appearing aboveground. However, in some cases on the sandy soils, more plants appeared where 400 pounds per acre of the 8–16–8 fertilizer were applied.

TABLE 6.—*Number of cotton plants appearing above ground per 50-foot row for various placements and rates of application of 8–16–8 fertilizer, 1931*

Fertilizer placement	Rate applied per acre (pounds)	Norfolk very fine sandy loam;[1] planted Apr. 16			
		Apr. 24	Apr. 29	May 6	May 19[2]
No fertilizer		5 ±1.2	220± 8.2	203±11.8	153± 9.7
1.75-inch band 2 inches below seed	200	4 ± .7	189±10.0	143±13.5	74± 9.4
Bands 3.5 inches to each side, 2 inches below level of seed	200	1 ± .3	206±12.1	188±12.8	137± 8.6
Mixed with soil below seed	200	3 ± .5	190± 9.6	152±12.3	83± 7.3
1.75-inch band 2 inches below seed	400	1 ± .3	144±10.1	118±14.2	28± 5.7
Bands 3.5 inches to each side, 2 inches below level of seed	400	1 ± .3	181± 8.5	178±13.8	138±11.8
Mixed with soil below seed	400	2 ± .4	168±17.2	109±14.2	37± 6.6
1.75-inch band 2 inches below seed	600	2 ± .4	131± 7.7	89±11.3	10± 2.0
Bands 3.5 inches to each side, 2 inches below level of seed	600	.4± .1	168± 9.1	159±10.7	125± 8.4
Mixed with soil below seed	600	2 ± .8	130± 9.0	101±12.4	23± 4.3

[1] On no-fertilizer plots, soil stirred 1.75 inches wide to depth of 2 inches below the seed.
[2] Final counts include only living plants.

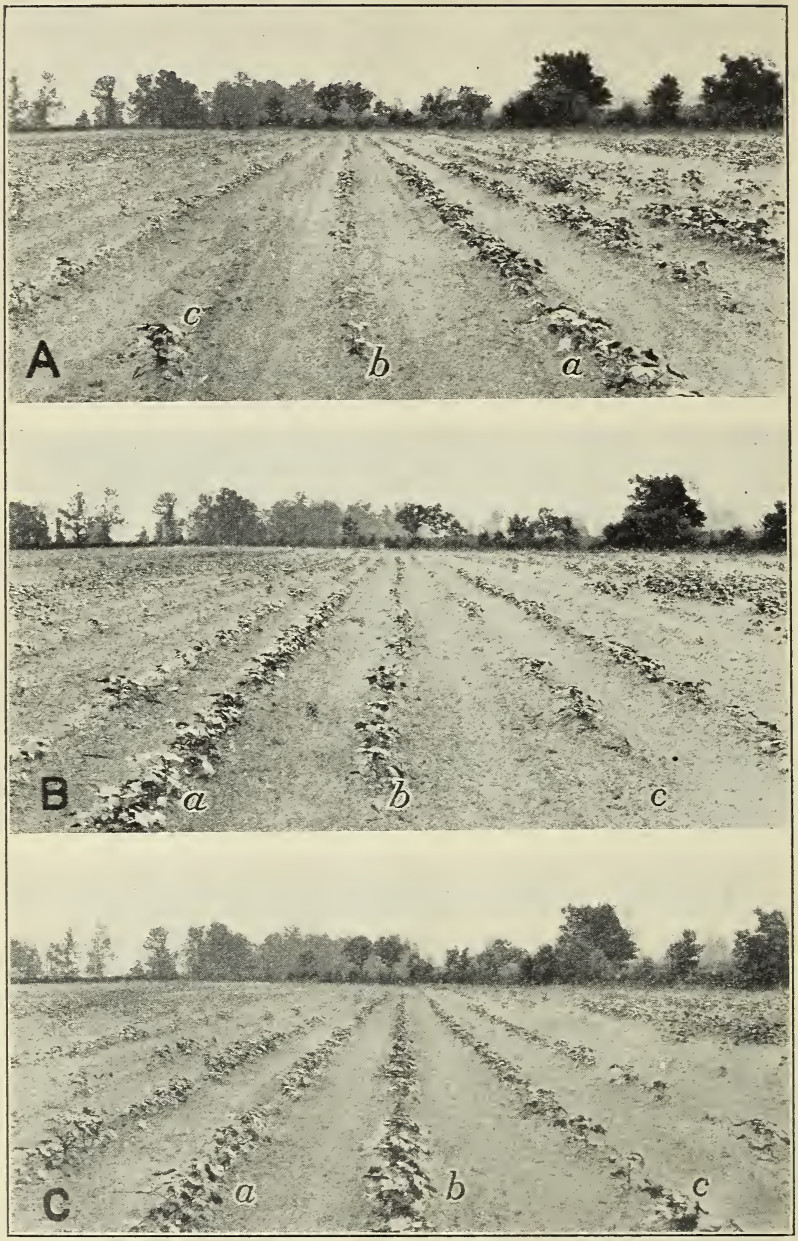

FIGURE 8.—Cotton planted April 16, photographed June 25, on Norfolk very fine sandy loam, Florence, S. C., 8-16-8 fertilizer applied as follows: A.—1.75-inch band 2 inches below the seed: *a*, 200 pounds per acre; *b*, 400 pounds per acre; *c*, 600 pounds per acre. B.—Mixed with the soil below the seed: *a*, 200 pounds per acre; *b*, 400 pounds per acre; *c*, 600 pounds per acre. C.—Bands 3.5 inches to each side of and 2 inches below the level of the seed: *a*, 200 pounds per acre; *b*, 400 pounds per acre, *c*, 600 pounds per acre.

TABLE 6.—*Number of cotton plants appearing above ground per 50-foot row for various placements and rates of application of 8–16–8 fertilizer, 1931*—Contd.

Fertilizer placement	Rate applied per acre (pounds)	Norfolk coarse sand; [1] planted Apr. 21			Cecil sandy clay loam; [2] planted May 1		
		May 4	May 11	May 22 [3]	May 10	May 13	May 26 [2]
No fertilizer		268± 7.6	241±6.9	217± 6.1	153±14.1	408± 6.2	460±8.7
1.75-inch band 2 inches below seed	200	188±11.4	202±9.1	143±10.0	178± 6.5	410± 6.5	450±8.4
Bands 3.5 inches to each side, 2 inches below level of seed	200	262± 7.5	232±8.6	204± 8.6	178± 8.4	406± 6.4	439±7.3
Mixed with soil below seed	200	226± 8.7	227±5.4	157± 8.6	150± 6.5	401± 7.2	451±5.1
1.75-inch band 2 inches below seed	400	97± 7.8	137±7.9	81± 6.1	155± 4.9	393± 6.8	412±6.2
Bands 3.5 inches to each side, 2 inches below level of seed	400	258± 3.3	245±4.8	218± 5.4	199± 7.0	411± 4.0	443±4.0
Mixed with soil below seed	400	117± 7.3	151±6.3	80± 7.3	117±10.6	385± 9.1	445±7.7
1.75-inch band 2 inches below seed	600	109± 4.9	147±3.6	87± 3.8	144± 8.1	398± 8.4	427±5.5
Bands 3.5 inches to each side, 2 inches below level of seed	600	257± 5.9	247±6.1	219± 9.2	203± 6.5	412± 8.2	452±5.0
Mixed with soil below seed	600	125± 9.1	151±8.7	75± 6.8	90± 6.4	355±11.3	403±7.4

[1] On no-fertilizer plots, soil stirred 3.5 inches wide to depth of 3 inches below the seed.
[2] On no-fertilizer plots, soil stirred 1.75 inches wide to depth of 2 inches below the seed.
[3] Final counts include only living plants.

MOVEMENTS OF SOLUBLE SALTS IN THE SOIL

It was necessary to know how much soluble fertilizer remained where it was placed and how much came into contact with the seed during the germination period in order to explain the effects of different placements on the crop. The amount by which the concentration of soluble salts in the seed zone of a fertilized row exceeds that of its unfertilized check may be used as a measure of the quantity of fertilizer that has been moved from its original location into contact with the seed. Accordingly, the concentrations of soluble salts in the seed zones were determined several times for each treatment soon after planting. Later in the season determinations of the amount remaining where it was placed and the distance to which some of the fertilizer had spread were also obtained.

METHOD OF DETERMINING MOVEMENT OF SALTS

Samples of soil were obtained for determinations of their soluble-salt contents in the following manner: A hole was dug in the row about 4 inches deep, and the side of the hole at right angles to the row was gradually cut away with a spatula until a seed was exposed as shown in Figure 9. A corkborer was then pushed into the row with the seed inside it, as illustrated. When the borer was removed it contained a core of soil 1 inch in diameter and 5 inches long with several seeds at its center. This soil is here considered to be the seed zone. Four such cores were gathered for each sample, screened through a 10-mesh sieve and thoroughly mixed. A 25-cubic-centimeter sample of the fine soil was then placed in a 150-cubic-centimeter wide-mouthed bottle, 100 cubic centimeters of distilled water was added, the bottle was tightly closed and shaken at intervals during 24 to 36 hours. The quantity of soluble salts in the solution was determined with a Wheatstone bridge by the method developed by the United States Bureau of Soils.[5] This method was shown to give results sufficiently accurate for the present purpose by making the same determination on a few

[5] DAVIS, R. O. E. THE USE OF THE ELECTROLYTIC BRIDGE FOR DETERMINING SOLUBLE SALTS. U. S. Dept. Agr. Circ. 423, 14 p., illus. 1927.

samples by a much longer but more accurate method and comparing the results.

EFFECT OF PLACEMENT OF FERTILIZER

The results given in Tables 7 and 8 show clearly that soluble salts moved rapidly in these soils. A few of the results appear to be out of line, probably because the samples were taken at points that were not representative for the row. This was most likely to happen in the case of the mixed-with-the-soil placement because the degree of mixing was not uniform and left more fertilizer near the seed at some points in the row than at others.

TABLE 7.—*Concentration of soluble salts in parts per million of the soil within one-half inch of the seed as a result of various placements of 4–8–4 fertilizer applied at the rate of 800 pounds per acre, 1931*

Test No.	Fertilizer placement	Norfolk very fine sandy loam; fertilizer applied Apr. 16			Norfolk coarse sand; fertilizer applied Apr. 23				Cecil sandy clay loam; fertilizer applied May 1		
		Apr. 17	Apr. 20	Apr. 30	Apr. 24	Apr. 28	May 6	May 13	May 9	May 16	May 25
	No fertilizer	120	90	71	38	34	70	34	39	52	67
	1.75-inch band:										
1	1 inch below seed	241	1,032	1,335	271	1,311	4,315	1,591	191	703	1,235
2	2 inches below seed	163	259	1,173	38	259	3,329	901	52	146	243
3	3 inches below seed	179	83	621	41	65	645	223	54	59	65
4	4 inches below seed	196	175	337	42	30	53	37	(1)	-----	-----
5	2 inches below seed (seed pressed in furrow covered with loose soil)	197	225	1,320	51	144	451	60	(1)	-----	-----
	3.5-inch band:										
6	1 inch below seed	641	1,422	1,266	290	2,004	3,228	547	94	122	367
7	2 inches below seed	273	284	907	62	188	1,444	285	51	65	93
8	3 inches below seed	179	172	807	53	39	491	43	43	45	43
9	4 inches below seed	167	79	217	37	32	53	42	(1)	-----	-----
	Bands 1.5 inches to each side:										
10	1 inch below level of seed	114	159	283	63	605	645	226	39	96	131
11	2 inches below level of seed	120	123	217	37	44	143	57	43	41	71
12	3 inches below level of seed	133	99	155	36	38	83	38	42	47	70
	Bands 3.5 inches to each side:										
13	1 inch below level of seed	117	87	70	59	33	72	38	42	59	61
14	2 inches below level of seed	113	85	77	37	35	50	33	47	76	101
15	3 inches below level of seed	115	84	68	40	32	50	52	42	58	50
16	2 inches below level of seed (soil stirred below seed)	124	87	76	49	38	82	40	56	83	53
17	2 inches below level of seed (seed pressed in furrow covered with loose soil)	119	88	102	42	32	50	38	(1)	-----	-----
	⅛ of fertilizer in contact with seed:										
18	⅞ in placement No. 2	4,385	600	4,137	4,126	1,904	3,783	1,359	(1)	-----	-----
19	⅞ in placement No. 3	4,568	544	3,463	3,891	2,443	2,685	788	1,644	2,047	978
20	⅞ in placement No. 14	1,940	1,229	1,776	4,001	2,008	2,083	1,349	1,977	1,585	208
	¼ of fertilizer in contact with seed:										
21	¾ in placement No. 3	14,499	2,893	4,568	7,045	4,559	5,239	2,271	(1)	-----	-----
22	¾ in placement No. 14	10,769	2,595	2,822	8,926	4,004	3,986	2,922	3,037	3,929	3,113
23	All fertilizer in contact with seed	36,062	14,358	11,819	45,387	7,278	9,345	3,936	5,763	5,691	8,873
24	Mixed with soil below seed	203	349	1,202	1,596	2,723	2,387	828	129	521	1,300
25	Band 1.5 inches to one side, 2 inches below level of seed	122	135	250	(1)	-----	-----	-----	(1)	-----	-----
26	Band 3.5 inches to one side, 2 inches below level of seed	123	92	91	(1)	-----	-----	-----	(1)	-----	-----
27	¼ of fertilizer on surface, ¾ in placement No. 14	120	841	85	(1)	-----	-----	-----	(1)	-----	-----

[1] Tests were not conducted.

In most cases where the fertilizer had been placed in bands 2 inches or less below the seed, or mixed with the soil, the quantity of salt in the seed zone was significantly higher than those of the checks the day after planting. In the Norfolk very fine sandy loam a slight amount of salt was brought into contact with the seed from a depth

of 4 inches during a single day. In both the fine sandy loam and coarse sand the amount of salts in the seed zones increased rapidly for about two weeks when the fertilizer had been placed 1 or 2 inches below the seed. So far as observed no fertilizer when applied at the usual rates was carried into contact with the seed from the bands 3.5 inches to both sides of the seed. Very small amounts were moved into the seed zones, however, from bands placed 1.5 inches to the sides at all depths tried, but this movement was less marked at a depth 3 inches below the seed. Salts moved much more slowly and for shorter distances to the sides than upward and downward. In general, for bands either directly below or at the sides the quantity coming into contact with the seed diminished rapidly as the distance increased from the seed to the point where the fertilizer was placed.

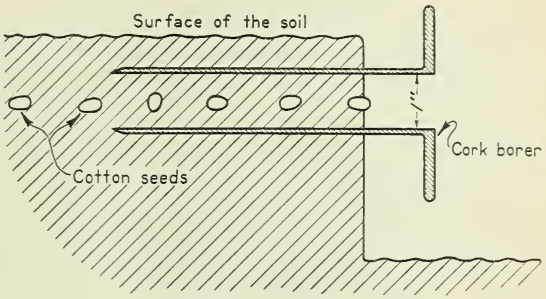

FIGURE 9.—Longitudinal section of a row showing the method of taking samples for determinations of the soluble salt in the seed zone

The determinations for the very fine sandy loam on April 20 were made after a 0.3-inch rain which appeared to carry downward much of the soluble material in this soil. In most cases the quantities of salts in the seed zones for a day or two were greatly reduced, but where part of the fertilizer was placed on the surface of the soil the quantity was greatly increased by the same cause. This soluble material began to rise again almost immediately, as is indicated by determinations on April 22 in Table 8. The determinations made for this soil on April 30 and May 1 given in Tables 7 and 8 indicate that salts were being carried upward at this time and probably had been moving in this direction during most of the previous week.

TABLE 8.—*Concentrations of soluble salts in parts per million of the soil within one-half inch of the seed as a result of applications of 8–16–8 fertilizer at several rates and placements, 1931*

Fertilizer placement	Rate of application per acre (pounds)	Norfolk very fine sandy loam; fertilizer applied Apr. 16				Norfolk coarse sand; fertilizer applied Apr. 21									Cecil sandy clay loam; fertilizer applied May 1		
		Apr. 17	Apr. 20	Apr. 22	May 1	Apr. 23	Apr. 25	Apr. 27	May 4	May 5	May 7	May 12	May 13	May 18	May 9	May 16	May 25
No fertilizer	----	114	90	126	68	36	48	30	52	57	50	54	27	30	46	55	63
1.75-inch band 2 inches below seed	200	114	152	179	849	40	41	33	---	308	---	137	---	---	47	52	83
Bands 3.5 inches to each side 2 inches below level of seed	200	114	87	120	82	42	49	30	---	44	---	39	---	---	46	44	56
Mixed with soil below seed	200	119	134	437	541	42	60	41	---	263	---	92	---	---	52	75	374
1.75-inch band 2 inches below seed	400	110	161	261	903	40	63	97	---	356	---	171	---	---	51	71	198
Bands 3.5 inches to each side 2 inches below level of seed	400	110	122	136	86	38	52	32	---	39	---	42	---	---	43	58	64
Mixed with soil below seed	400	169	474	1, 401	670	171	482	694	---	419	---	93	---	---	115	207	866
1.75-inch band 2 inches below seed	600	124	170	532	1, 400	45	100	141	611	747	559	988	223	353	55	67	650
Bands 3.5 inches to each side 2 inches below level of seed	600	157	169	226	135	37	51	33	---	61	---	37	---	---	43	53	56
Mixed with soil below seed	600	762	306	1, 753	893	316	583	780	---	804	---	1, 270	---	---	134	1, 168	830

Soil moisture in the coarse sand was maintained at nearly 5 per cent from planting time until May 12 by a succession of light rains with periods of capillary rise between them. This brought about a steady increase in the concentration of the salts in solution in the seed zones where the fertilizer was placed 1, 2, and 3 inches below the seed and where it was mixed with the soil, until a heavy rain on May 12 greatly decreased it.

The first set of determinations for the Cecil sandy clay loam was made eight days after planting, during which time over 8 inches of rain fell. The quantities of soluble salts in the seed zones in this soil were found to be very small as compared with those in the other soils.

EFFECT OF RATE OF APPLICATION OF FERTILIZER

Although from Table 8 no salt appears to have been carried into the seed zones from bands 3.5 inches to the sides of the seed at normal or half normal rates of application of 8–16–8 fertilizer in any of the soils or at the one and one-half rate in the coarse sand and sandy clay loam, small amounts were thus carried at the highest rate in the very fine sandy loam. The quantity from this placement at the highest rate was about the same as, or slightly less than, that from the 1.75-inch band placed 2 inches below the seed or the mixed-with-the-soil placement at the lowest rate. From the latter two placements the amount of salt brought into the seed zone increased rapidly with increases in the rate of application.

SINGLE VERSUS DOUBLE-STRENGTH FERTILIZERS

The two fertilizers may be compared by the results given in Table 8 for the double-strength fertilizer with those for the same placements given in Table 7 for the 4–8–4 fertilizer. It appears that no salt was carried into contact with the seed from placements 3½ inches to the sides of the seed where either fertilizer was used at the normal rate. With other placements, salt was carried into the seed zone from applications of either fertilizer. In all of the soils the quantity was greater when fertilizer of ordinary strength was used. This may be due to the fact that 100 pounds of the 4–8–4 fertilizer contained 37 pounds of soluble salts, while the equivalent amount of 8–16–8 fertilizer contained only 32 pounds.

SPREAD OF FERTILIZER SALTS DURING THE GROWING SEASON

The quantity of soluble salts present 100 days after planting was determined for various points extending from the surface of the soil to a depth of 15 inches in the row of plants, and from the center of the fertilizer band to points 5 inches to the sides of it. The placement selected was the 1.75-inch band located 2 inches below the seed. In general the results obtained with this placement should apply to most of the others in the same soil. Cores of soil were taken for each point by inserting a cork borer parallel with the row, and the soluble salt content of the composite sample was determined in the manner previously described. Additional samples were then obtained in like manner from another plat for duplicate determinations. Averages of these determinations are given in Table 9.

TABLE 9.—*Concentrations of soluble salts in parts per million in the soil at various distances from the original position of the fertilizer three months after its application in a 1.75-inch band, 2 inches below the seed*

Depth	Fertilized					Unfertilized center of row
	Center of row	1 inch to side of row	2 inches to side of row	3 inches to side of row	5 inches to side of row	
NORFOLK VERY FINE SANDY LOAM						
At surface	365± 50					107±23
1 inch below surface	161± 4					
2 inches below surface	229± 25					64± 8
3 inches below surface	2,881±160	604± 44	100±29	70±14	52±1	61± 5
4 inches below surface	448±167					58± 1
5 inches below surface	78± 3					
6 inches below surface	146± 24					
10 inches below surface	60± 4					54± 4
15 inches below surface	68± 5					
NORFOLK COARSE SAND						
At surface	1,210±191					93± 4
1 inch below surface	633± 65					
2 inches below surface	677± 86					
3 inches below surface	4,063±557	3,013±225	687±65	272±20	87±3	58± 1
4 inches below surface	437± 53					44± 1
5 inches below surface	723± 85					
6 inches below surface	349± 13					
10 inches below surface	381± 18					60± 2
15 inches below surface	209± 11					
CECIL SANDY CLAY LOAM						
At surface	209± 1					61± 7
1 inch below surface	314± 8					
2 inches below surface	499± 26					
3 inches below surface	3,469±177	291± 29	267±21	128±12	152±7	121± 2
4 inches below surface	272± 22					162±15
5 inches below surface	156± 25					
6 inches below surface	140± 26					
10 inches below surface	196± 11					278± 3

The 4–8–4 fertilizer contained 37 per cent of water-soluble salts. A core of soil taken from the contact placement was estimated to consist of 9 parts of soil to 1 part of fertilizer. One day after planting, such cores from the fine sandy loam and coarse sand contained 3.61 and 4.54 per cent, respectively, of total soluble salts, and thus at this time practically all of the salts were still present in the fertilizer band in a water-soluble condition. After 15 days, however, this content had shrunk to about 1 per cent in each of the soils, and after 100 days, as shown in Table 9, it had been reduced still further to about 0.3 or 0.4 per cent. Thus, after three months about 10 per cent of the water-soluble salts originally present was still located in the fertilizer band. The balance either had been rendered insoluble in water, diffused into the surrounding soil, leached out altogether, or had been removed by the plants.

In the coarse sand to a distance of 5 inches to the sides of the row and to a depth of at least 15 inches below the surface, and probably much deeper, the quantities of soluble salts were in excess of those found at similar points in the unfertilized rows. The evidence is clear that more salts were present also in the fine sandy loam surrounding the fertilizer bands than at corresponding points in the unfertilized rows, but, in this case, for a distance of only 3 inches in each direction from the fertilizer band. In the sandy clay loam this limit of spread appears to have been about 2 inches.

In order to gain an idea of the proportion of the water-soluble salts originally in the fertilizer application remaining in that condition 100 days after planting, the amounts by which the determinations

shown in Table 9 exceed their appropriate checks were totaled and to this total were added interpolated amounts for the intermediate soil. From these calculations it appears that at least one-half of the water-soluble fertilizer placed in the coarse sand was still present somewhere in the row in a water-soluble condition. In the other soils, however, it is clear that a large proportion of the fertilizer is no longer present in a water-soluble condition.

Of the three soils used, the coarse sand has the least capacity for reverting phosphates, adsorbing soluble salts, and resisting leaching, but nevertheless at this time it contained the largest quantity of water-soluble salts. The salts were also much more widely dispersed throughout the row. Therefore it seems probable that considerable proportions of the soluble fertilizer in the other soils had been rendered insoluble in water and remained in this condition within a few inches of the point of application. This fertilizer may be just as available to the plant as before, but it will no longer move about with the soil moisture.

FIGURE 10.—Cotton plants growing in pure quartz sand moistened to 45 per cent of its holding capacity with soil solutions of various concentrations. Each soil solution contained all essential elements in the same proportions, but the percentages of total salts differed as shown by the labels

CONCENTRATION OF THE SOIL SOLUTION

Sand cultures in pots were made under controlled moisture and temperature conditions to study the salt concentration of the solutions in contact with cottonseed most favorable to germination of seed and growth of young plants. Interesting comparisons may be made between the results of these pot experiments and the concentration of fertilizer salts in the field experiments resulting from various placements of fertilizers in relation to the seed.

In the pot tests, under optimum conditions of moisture and temperature, delinted Acala cottonseed germinated most rapidly and grew most vigorously, as shown in Figure 10, when the pure quartz sand was moistened to 45 per cent of its holding capacity with solutions containing between 0.047 per cent and 0.202 per cent of soluble salts, which included balanced proportions of all the essential ions. The use of solutions containing less than 0.05 per cent or more than 0.2 per cent of salts resulted in progressively slower appearance of seedlings aboveground and slower growth. No plants came up when a solution containing 2.73 per cent of fertilizer salts was used. These results obtained under controlled conditions check very well with the field results which therefore have greater significance than they

would otherwise have. The concentrations of the soil solutions in contact with the seed and roots of the small plants in the field are compared with the corresponding stand counts in Tables 10 and 11. The lowest concentrations found in the field were those of the soil solutions of the unfertilized rows, and these already contained sufficient salts to insure rapid come-up. As the concentration increased the rate of appearance of seedlings at the surface tended to decrease. The results were erratic but in general it may be said that the numbers obtained in the first germination count were reduced to about one-half in each soil when the concentration approached 0.3 per cent. Germination was considerably delayed by concentrations between 0.3 per cent and 1.0 per cent, but the final stand was nevertheless as good as that on the unfertilized plots where the concentration of soluble salts did not at any time exceed 1 per cent. Beyond 1 per cent the final stand was reduced. A few plants grew in contact with the soil solution temporarily containing 3 per cent of soluble salts. Growth appeared to be most rapid when the concentration was about 0.2 per cent. (Compare with Fig. 10.)

TABLE 10.—*Concentrations of the soil solutions in the sandy soils as a result of various fertilizer treatments and the corresponding numbers of seedlings above ground on the dates shown*

Fertilizer			Norfolk very fine sandy loam				
			Concentration of the soil solution		Seedlings above-ground Apr. 29	Concentration of the soil solution May 1	Seedlings above-ground May 6
Placement	Analysis	Rate of application	Apr. 17	Apr. 20			
		Pounds per acre	*Per cent*	*Per cent*	*Number*	*Per cent*	*Number*
No fertilizer			0.13	0.12	193	0.10	186
Bands 3.5 inches to each side 3 inches below seed level	4-8-4	800	.13	.08	194	.10	179
Bands 3.5 inches to each side 2 inches below seed level	do	800	.12	.09	172	.11	163
Do	4-12-4	400	.12	.16	176	.06	215
Do	8-16-8	200	.13	.09	206	.11	188
Do	do	400	.12	.12	181	.12	178
Do	do	600	.17	.17	168	.19	159
Do	3-10-6	800	.13	.17	198	.16	227
Do	6-10-6	800	.13	.17	169	.08	186
Bands 3.5 inches to each side 1 inch below seed level	4-8-4	800	.13	.09	183	.10	174
Bands 1.5 inches to each side 3 inches below seed level	do	800	.15	.10	232	.22	210
Bands 1.5 inches to each side 2 inches below seed level	do	800	.13	.12	238	.30	211
Bands 1.5 inches to each side 1 inch below seed level	do	800	.22	.16	224	.40	203
Bands 3.5 inches to one side 2 inches below seed level	do	800	.14	.09	123	.13	198
Bands 1.5 inches to one side 2 inches below seed level	do	800	.13	.14	128	.35	190
One-fourth on surface, three-fourths bands 3.5 inches to each side 2 inches below seed level	do	800	.13	.84	196	.12	171
3.5-inch band 4 inches below seed	do	800	.18	.08	230	.30	201
1.75-inch band 4 inches below seed	do	800	.22	.18	213	.47	215
3.5-inch band 3 inches below seed	do	800	.20	.17	195	1.13	171
1.75-inch band 3 inches below seed	do	800	.20	.08	182	.87	173
1.75-inch band 2 inches below seed	4-12-4	400	.13	.17	154	.97	144
Do	8-16-8	200	.13	.15	189	1.18	143
Mixed with the soil below seed	do	200	.13	.13	190	.76	152
1.75-inch band 2 inches below seed	do	400	.12	.16	144	1.26	118
Do	do	600	.14	.17	131	1.95	89
Mixed with the soil below seed	do	400	.19	.47	168	.94	109
Do	do	600	.84	.31	130	1.25	101
Do	4-8-4	800	.22	.35	141	1.68	129
3.5-inch band 2 inches below seed	do	700	.31	.28	118	1.27	122
1.75-inch band 2 inches below seed	do	800	.18	.26	147	1.64	121
Do	3-10-6	800	.13	.23	84	1.71	105
Do	6-10-6	800	.15	.31	69	2.34	68
3.5-inch band 1 inch below seed	4-8-4	800	.71	1.42	11	1.77	27
1.75-inch band 1 inch below seed	do	800	.27	1.03	13	1.86	19

TABLE 10.—*Concentrations of the soil solutions in the sandy soils as a result of various fertilizer treatments and the corresponding numbers of seedlings aboveground on the dates shown*—Continued

Fertilizer			Norfolk coarse sand						
Placement	Analysis	Rate of application	Concentration of the soil solution		Seedlings above ground May 4	Concentration of the soil solution May 6	Seedlings aboveground May 11	Concentration of the soil solution May 13	Seedlings aboveground May 22
			Apr. 24	Apr. 28					
		Pounds per acre	*Per cent*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*
No fertilizer			0.08	0.06	316	0.12	303	0.05	257
Bands 3.5 inches to each side 3 inches below seed level	4–8–4	800	.08	.06	332	.10	312	.08	257
Bands 3.5 inches to each side 2 inches below seed level	do	800	.07	.07	323	.10	294	.05	261
Do	4–12–4	400	.07	.07	263	.10	230	.07	208
Do	8–16–8	200	.09	.06	262	.09	232	.06	203
Do	do	400	.09	.06	257	.08	245	.07	217
Do	do	600	.07	.07	257	.12	247	.06	219
Do	3–10–6	800	.07	.07	247	.10	227	.07	194
Do	6–10–6	800	.07	.07	269	.12	261	.06	239
Bands 3.5 inches to each side 1 inch below seed level	4–8–4	800	.12	.07	278	.14	275	.06	235
Bands 1.5 inches to each side 3 inches below seed level	do	800	.07	.08	348	.17	341	.06	289
Bands 1.5 inches to each side 2 inches below seed level	do	800	.07	.09	336	.29	345	.09	281
Bands 1.5 inches to each side 1 inch below seed level	do	800	.13	1.21	213	1.29	271	.36	170
Bands 3.5 inches to one side 2 inches below seed level	do	800	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Bands 1.5 inches to one side 2 inches below seed level	do	800	(1)	(1)	(1)	(1)	(1)	(1)	(1)
One-fourth on surface, three-fourths bands 3.5 inches to each side 2 inches below seed level	do	800	(1)	(1)	(1)	(1)	(1)	(1)	(1)
3.5-inch band 4 inches below seed	do	800	.07	.07	316	.11	312	.07	270
1.75-inch band 4 inches below seed	do	800	.08	.06	359	.11	355	.06	294
3.5-inch band 3 inches below seed	do	800	.11	.08	124	.98	225	.07	182
1.75-inch band 3 inches below seed	do	800	.08	.13	176	1.29	244	.36	190
1.75-inch band 2 inches below seed	4–12–4	400	.07	.15	146	.56	181	.15	132
Do	8–16–8	200	.08	.07	187	.72	201	.27	142
Mixed with the soil below seed	do	200	.08	.08	226	.53	226	.15	156
1.75-inch band 2 inches below seed	do	400	.08	.19	97	.71	136	.22	81
Do	do	600	.09	.28	109	1.49	147	1.58	87
Mixed with the soil below seed	do	400	.34	1.39	117	.84	150	.15	80
Do	do	600	.63	1.56	124	1.61	150	2.03	75
Do	4–8–4	800	3.19	5.45	12	4.77	39	1.32	34
3.5-inch band 2 inches below seed	do	700	.12	.38	48	2.89	126	.46	106
1.75-inch band 2 inches below seed	do	800	.08	.52	11	6.66	33	1.44	26
Do	3–10–6	800	.08	2.01	61	1.10	89	.82	53
Do	6–10–6	800	.20	2.24	34	2.65	60	.84	32
3.5-inch band 1 inch below seed	4–8–4	800	.58	4.01	1	6.46	4	.87	4
1.75-inch band 1 inch below seed	do	800	.54	2.62	4	8.63	9	2.55	6

[1] Tests were not conducted.

TABLE 11.—*Concentration of the soil solutions in Cecil sandy clay loam as a result of various fertilizer treatments and the corresponding numbers of seedlings aboveground on the dates shown*

Fertilizer			Concentration of the soil solution May 9	Seedlings aboveground		Concentration of the soil solution		Seedlings aboveground May 26
Placement	Analysis	Rate of application		May 10	May 13	May 16	May 25	
		Pounds per acre	*Per cent*	*Number*	*Number*	*Per cent*	*Per cent*	*Number*
No fertilizer			0.04	176	417	0.07	0.08	452
Bands 3.5 inches to each side 3 inches below seed level	4-8-4	800	.04	198	399	.07	.06	432
Bands 3.5 inches to each side 2 inches below seed level	do	800	.04	211	427	.09	.12	456
Do	8-16-8	200	.04	178	406	.05	.07	439
Do	do	400	.04	199	406	.07	.08	443
Do	do	600	.04	203	412	.06	.07	452
Bands 3.5 inches to each side 1 inch below seed level	4-8-4	800	.04	216	413	.07	.07	453
Bands 1.5 inches to each side 3 inches below seed level	do	800	.04	205	430	.06	.09	464
Bands 1.5 inches to each side 2 inches below seed level	do	800	.04	200	406	.05	.06	438
Bands 1.5 inches to each side 1 inch below seed level	do	800	.03	189	411	.12	.16	447
3.5-inch band 3 inches below seed	do	800	.04	172	405	.06	.05	446
1.75-inch band 3 inches below seed	do	800	.05	170	384	.07	.08	463
3.5-inch band 2 inches below seed	do	800	.05	171	421	.08	.11	457
1.75-inch band 2 inches below seed	do	800	.05	157	409	.18	.29	446
3.5-inch band 1 inch below seed	do	800	.08	142	402	.15	.44	450
1.75-inch band 2 inches below seed	8-16-8	200	.04	178	410	.06	.10	450
Do	do	400	.05	155	393	.09	.24	412
Do	do	600	.05	144	398	.08	.79	427
Mixed with soil below seed	do	200	.05	150	401	.09	.45	451
Do	do	400	.10	117	385	.25	1.05	445
Do	4-8-4	800	.11	139	394	.63	1.57	437
Do	8-16-8	600	.12	90	355	1.41	1.00	390
1.75-inch band 1 inch below seed	4-8-4	800	.17	97	392	.85	1.49	444

Seed and seedlings were examined from time to time during the first month after planting. On April 22, or six days after planting in the very fine sandy loam, seedlings were carefully removed from the soil. Between 20 and 25 were gathered for each of a number of placements of the fertilizer. Typical plants are shown in Figure 11. No signs of germination were observed in any of the seed found in contact with the fertilizer applied at the full rate. Very tiny roots (fig. 11) were found, however, on most of the seed in contact with one-fourth or one-eighth of the fertilizer applied, that is, with that applied at a rate of 100 to 200 pounds per acre. Where the fertilizer was placed either 1 or 2 inches below the seed, the plants were smaller than the check plants. The concentrations of the soil solutions in the seed zones two days earlier were 1 and 1.4 per cent for the 1.75 and 3.5 inch bands placed 1 inch below the seed and 0.2 and 0.28 per cent for those placed 2 inches below the seed.

Where the fertilizer was located 3.5 inches to the sides of the seed, the size and condition of the seedlings were about the same as those of the checks, which averaged 3 inches in length at this time. In all four cases where the fertilizer was placed 1.5 inches to the sides of the seed and in the case of the 3.5-inch band 4 inches below the seed, the plants were larger than the unfertilized ones. This was especially noticeable where the fertilizer was 1.5 inches to the sides at a depth 1 inch below that of the seed. In the latter case the plants were about

4 inches in length, and the concentration of salts in the soil solution on April 20 was 0.159 per cent. The plants about 3 inches in length were in contact at that time with soil solutions having concentrations of 0.08 to 0.11 per cent.

Seedlings from the same plats were examined again on May 4. Typical plants are shown in Figure 12. Where the fertilizer was put directly below the seed in this soil none of the plants was as large, on an average, as the unfertilized checks, although all the roots were now in contact with soil solutions of greater concentration than 1 per cent. Those fertilized at the sides were larger. The check plants averaged 5.5 inches, and those fertilized 1.5 and 3.5 inches to the sides about 7.5 and 6.5 inches in length, respectively. The concentrations of the soil solutions in contact with the roots for these

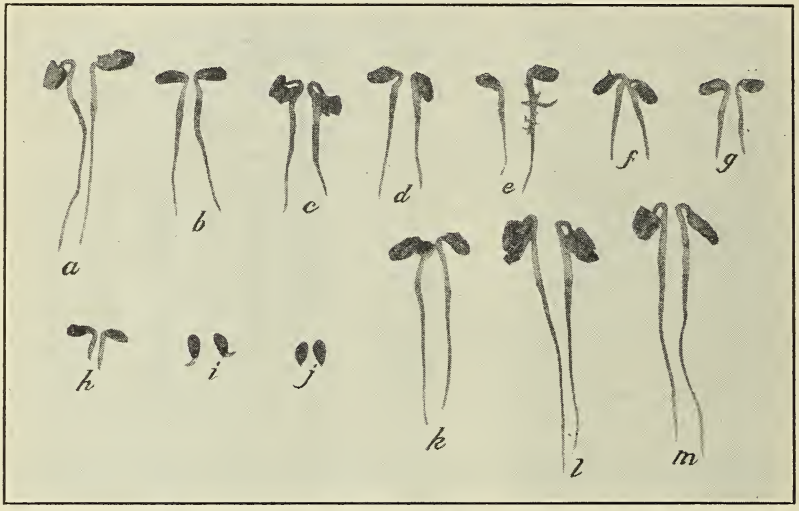

FIGURE 11.—Typical plants on April 22, or 6 days after planting, for various placements of 800 pounds per acre of 4–8–4 fertilizer in Norfolk very fine sandy loam: *a*, No fertilizer; *b*, 1.75-inch band 4 inches below seed; *c*, 1.75-inch band 3 inches below seed; *d*, 1.75-inch band 2 inches below (seed pressed into soil and covered loosely); *e*, 1.75-inch band 2 inches below; *f*, 1.75-inch band 1 inch below; *g*, 3.5-inch band 1 inch below; *h*, one-eighth contact; *i*, seven-eighths contact, 3.5 inches to sides; *j*, one-fourth contact, three-fourths at sides; *k*, all contact mixed with soil below seed; *l*, bands 1.5 inches to each side 2 inches below level of seed; *m*, bands 3.5 inches to sides 2 inches below level of seed

placements appear to have been about 0.1, 0.3, and 0.15 per cent, respectively.

Seedlings from the coarse sand were examined on April 28. At that time, five days after planting, the check plants were 1.25 to 1.5 inches in length. None of those with fertilizer placed below the seed, either in narrow bands or mixed with the soil, was as large as that. Those with the fertilizer located 3.5 inches to the sides of the seed at all levels tried and 1.5 inches to the sides at a level 3 inches below the seed were about the same in size as the unfertilized plants. Those with bands 1.5 inches to the sides and 1 inch below the seed level (soil solution concentration 1.21 per cent) were smaller than the checks (soil solution concentration 0.06 per cent), and those with the same bands 1.5 inches to the sides and 2 inches below the seed level (soil solution concentration 0.09 per cent) were the largest of all, measuring 1.75 inches in length on an average.

In each soil used in this study the concentration of the soil solution in the seed zone at planting time was in the range most favorable for germination without the addition of any fertilizer. It follows, therefore, that for best germination, fertilizer should be so placed that none of it will come into contact with the seed during the germination period.

Cotton seems to require a soil-solution concentration of about 0.07 per cent in the seed zone at planting and of about 0.2 per cent in

FIGURE 12.—Typical plants on May 4, or 18 days after planting for various placements of 800 pounds per acre of 4–8–4 fertilizer in Norfolk very fine sandy loam: *a*, No fertilizer; *b*, 1.75-inch band 4 inches below seed; *c*, 1.75-inch band 3 inches below seed; *d*, 1.75-inch band 2 inches below (seed pressed into soil and covered loosely); *e*, 1.75-inch band 2 inches below; *f*, 1.75-inch band 1 inch below; *g*, 3.5-inch band 1 inch below; *h*, one-eighth contact, seven-eighths 3.5 inches to sides; *i*, one-fourth contact, three-fourths at sides; *j*, all contact; *k*, mixed with soil below seed; *l*, bands 1.5 inches to each side 2 inches below level; *m*, bands 3.5 inches to sides 2 inches below level of seed

the root zone during the growing season. Soil-solution conditions reasonably close to those necessary for best germination and early growth were obtained in the field tests in a number of cases, for example, when 4–8–4 fertilizer was applied to the two lighter soils at a rate of 800 pounds per acre in narrow bands 1½ inches to each side and 2 or 3 inches below the level of the seed. In the Cecil soil placing the 1.75-inch band 2 inches below the seed also gave conditions for best results during the first few weeks. These placements also made excellent showings in the comparisons of germination and seedling growth recorded in this report.

While bands placed 1 and 2 inches directly below the seed produced excellent results in the clay loam under prevailing conditions, in the sandy soils this placement permitted too much soluble salt to come in contact with the seed. The side placements in the sandy soils permitted small amounts of plant food to be carried into the seed zone soon after planting, but the same placement in the clay soil did not.

The fertilizer placements which produced nearly optimum conditions of soil concentration for germination and early growth also gave high yields.

ROOT SYSTEM

Fertilizer should be placed where the roots can obtain the optimum amount of food throughout the season and where it will not injure the root system. A number of observations, made during the present study, have some bearing upon these points.

Two weeks after planting, seed had germinated where the fertilizer was placed 1 inch below them, but in the lighter soils few of the seedlings had pushed through the surface, and most of them had shriveled root tips. Where the fertilizer was placed 2 inches below the seed or mixed with the soil a considerable proportion of the plants also had shriveled root tips. One month after planting, only a few of these plants were still living in the coarse sand and fine sandy loam, although in the sandy clay loam no injury was observed from the same placements. Such dead plants as were examined clearly showed injury to the primary root, and no lateral roots were visible.

When the primary root encountered the fertilizer band at depths of 3 and 4 inches below the seed zone in the lighter soils, lateral roots had appeared; and although the tip of the primary root was killed, many plants continued to grow. Although seedlings from all of the placement tests were examined, the only case of injured roots observed in the sandy clay loam was where 8–16–8 fertilizer at the rate of 600 pounds per acre had been placed 2 inches below the seed. With this high rate of application, however, the ends of the taproots of the majority of the seedlings were dead where they had encountered the fertilizer zone. These plants had plenty of lateral roots in a healthy condition and one month after planting appeared to be growing as vigorously as any of the other plants.

The above observations seem to show that if the concentration of soluble salts seriously injures the taproot before any laterals have developed, the plant dies.

No injury to the roots was observed as a result of side placements in any case. Since during early growth the development of lateral roots is slow as compared with that of the taproot, it is unlikely that any lateral roots would reach the fertilizer band even at the 1.5 inches-to-the-sides placement until a network of other roots was established.

Three months after planting a mass of root hairs had formed around the fertilizer band in all of the placements and in all of the soils, regardless of the position of the fertilizer. The large roots were distributed throughout the soil and subsoil without any apparent reference to the position of the fertilizer.

YIELD

The rainfall was below normal for the season, and early adverse weather conditions for the very fine sandy loam and coarse sand not only caused injury to germination but caused a large number of the seedlings to die. These conditions of course affected the yields which are given in Tables 12 and 13. As indicated in those yield tables by the number of mature plants, the stand was excellent on the sandy clay loam, satisfactory in a number of tests on the coarse sand, but rather inferior on the very fine sandy loam. For the tests having only a few mature plants per 50-foot row, attention has been called to the severe injury to germination, and obviously their yields need not be discussed.

TABLE 12.—*Yield per acre of seed cotton and number of mature plants per 50 feet of row for various placements of 800 pounds per acre of 4–8–4 fertilizer*

Test No.	Fertilizer placement	Norfolk very fine sandy loam				
		Yield				Plants, Oct. 19
		Sept. 17	Oct. 1	Oct. 20	Total	
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Number*
	No fertilizer	453	278	29	760±57	42
	1.75 inch band:					
1	1 inch below seed	35	54	33	122±37	2
2	2 inches below seed	116	197	58	371±65	7
3	3 inches below seed	392	294	49	735±83	19
4	4 inches below seed	754	279	29	1,062±71	40
5	2 inches below seed (seed pressed in furrow covered with loose soil)	138	228	62	428±69	8
	3.5-inch band:					
6	1 inch below seed	50	90	36	176±32	3
7	2 inches below seed	336	334	102	772±83	17
8	3 inches below seed	541	412	64	1,017±56	35
9	4 inches below seed	758	333	35	1,126±59	44
	Bands 1.5 inches to each side:					
10	1 inch below level of seed	637	390	30	1,057±51	37
11	2 inches below level of seed	777	349	21	1,147±61	44
12	3 inches below level of seed	806	316	21	1,143±38	47
	Bands 3.5 inches to each side:					
13	1 inch below level of seed	698	367	32	1,097±43	41
14	2 inches below level of seed	761	337	34	1,132±55	41
15	3 inches below level of seed	813	434	38	1,285±72	45
16	2 inches below level of seed (soil stirred below seed)	666	283	16	965±62	45
17	2 inches below level of seed (seed pressed in furrow covered with loose soil)	790	349	27	1,166±47	43
	One-eighth of fertilizer in contact with seed:					
18	Seven-eighths in placement No. 2	76	147	53	276±46	4
19	Seven-eighths in placement No. 3	204	429	134	767±55	12
20	Seven-eighths in placement No. 14	650	391	41	1,082±30	32
	One-fourth of fertilizer in contact with seed:					
21	Three-fourths in placement No. 3	61	129	40	230±52	5
22	Three-fourths in placement No. 14	222	198	49	469±63	12
23	All fertilizer in contact with seed	20	40	35	95±19	1
24	Mixed with soil below seed	336	412	87	835±85	17
25	Band 1.5 inches to one side, 2 inches below level of seed	514	297	42	853±49	36
26	Band 3.5 inches to one side, 2 inches below level of seed	669	342	38	1,049±76	41
27	One-fourth of fertilizer on surface, three-fourths in placement No. 14	807	568	52	1,427±76	40

TABLE 12.—*Yield per acre of seed cotton and number of mature plants per 50 feet of row for various placements of 800 pounds per acre of 4–8–8 fertilizer*—Contd.

Test No.	Fertilizer placement	Norfolk coarse sand				Cecil sandy clay loam				
		Yield			Plants, Oct. 22	Yield				Plants, Oct. 19
		Sept. 14	Oct. 5	Total		Sept. 10	Sept. 29	Oct. 20	Total	
		Lbs.	*Lbs.*	*Lbs.*	*No.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*No.*
	No fertilizer	234	40	274±16	50	221	333	104	658±25	100
	1.75 inch band:									
1	1 inch below seed	29	40	69±20	2	646	308	57	1,011±47	100
2	2 inches below seed	138	92	230±37	8	626	246	43	915±30	99
3	3 inches below seed	369	121	490±21	45	631	270	46	947±52	101
4	4 inches below seed	474	122	596±30	59	(1)				
5	2 inches below seed (seed pressed in furrow covered with loose soil)	399	136	535±28	48	(1)				
	3.5-inch band:									
6	1 inch below seed	26	24	50±17	2	597	329	87	1,013±36	99
7	2 inches below seed	230	140	370±38	27	623	248	42	913±28	99
8	3 inches below seed	406	125	531±23	48	623	224	39	886±23	100
9	4 inches below seed	431	85	516±22	57	(1)				
	Bands 1.5 inches to each side:									
10	1 inch below level of seed	318	149	467±24	44	581	229	31	841±21	100
11	2 inches below level of seed	370	136	506±23	54	629	223	37	889±28	100
12	3 inches below level of seed	425	86	511±14	58	625	214	37	876±28	100
	Bands 3.5 inches to each side:									
13	1 inch below level of seed	464	194	658±28	53	552	267	52	871±35	100
14	2 inches below level of seed	456	150	606±26	60	561	234	36	831±21	99
15	3 inches below level of seed	464	155	619±29	54	541	239	36	816±18	99
16	2 inches below level of seed (soil stirred below seed)	452	122	574±13	62	521	249	50	820±29	98
17	2 inches below level of seed (seed pressed in furrow covered with loose soil)	389	158	547±20	54	(1)				
	One-eighth of fertilizer in contact with seed:									
18	Seven-eighths in placement No. 2	185	140	325±30	14					
19	Seven-eighths in placement No. 3	353	160	513±30	39	527	237	46	810±31	100
20	Seven-eighths in placement No. 14	442	228	670±53	36	519	229	51	799±20	100
	One-fourth of fertilizer in contact with seed:									
21	Three-fourths in placement No. 3	291	150	441±38	22	(1)				
22	Three-fourths in placement No. 14	169	165	334±55	14	516	249	55	820±30	99
23	All fertilizer in contact with seed	22	38	60±15	4	210	337	140	687±38	59
24	Mixed with soil below seed	136	143	279±25	12	527	223	37	787±23	98
25	Band 1.5 inches to one side, 2 inches below level of seed	(1)				(1)				
26	Band 3.5 inches to one side, 2 inches below level of seed	(1)				(1)				
27	One-fourth of fertilizer on surface, three-fourths in placement No. 14	(1)				(1)				

[1] Tests were not conducted.

TABLE 13.—*Yield per acre of seed cotton and number of mature plants per 50 feet of row for various placements and rates of application of 8–16–8 fertilizer*

Fertilizer		Norfolk very find sandy loam				
Placement	Rate of application per acre	Yield				Plants, Oct. 19
		Sept. 17	Oct. 1	Oct. 20	Total	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Number*
No fertilizer		452	364	54	870±57	48
1.75-inch band, 2 inches below seed	200	517	354	76	947±92	25
Bands 3.5 inches to each side, 2 inches below level of seed	200	589	299	32	920±37	41
Mixed with soil below seed	200	584	457	86	1,127±53	31
1.75-inch band, 2 inches below seed	400	164	190	56	410±74	8
Bands 3.5 inches to each side, 2 inches below level of seed	400	763	353	41	1,157±75	43
Mixed with soil below seed	400	286	303	89	678±76	13
1.75-inch band, 2 inches below seed	600	39	46	12	97±26	3
Bands 3.5 inches to each side, 2 inches below level of seed	600	545	432	51	1,028±60	38
Mixed with soil below seed	600	175	288	85	548±82	11

TABLE 13.—*Yield per acre of seed cotton and number of mature plants per 50 feet of row for various placements and rates of application of 8–16–8 fertilizer*—Con.

Fertilizer		Norfolk coarse sand				Cecil sandy clay loam				
Placement	Rate of application per acre	Yield			Plants, Oct. 22	Yield				Plants, Oct. 19
		Sept. 14	Oct. 5	Total		Sept. 10	Sept. 29	Oct. 20	Total	
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*No.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*No.*
No fertilizer		291	61	352±15	49	171	321	103	595±25	97
1.75-inch band, 2 inches below seed	200	402	131	533±21	33	466	222	42	730±26	98
Bands 3.5 inches to each side, 2 inches below level of seed	200	426	110	536±33	44	455	231	50	736±25	97
Mixed with soil below seed	200	456	104	560±26	40	466	218	40	724±15	99
1.75-inch band, 2 inches below seed	400	206	114	320±37	19	518	225	47	790±23	99
Bands 3.5 inches to each side, 2 inches below level of seed	400	413	152	565±25	52	544	239	49	832±25	98
Mixed with soil below seed	400	323	86	409±32	27	505	248	49	802±14	99
1.75-inch band, 2 inches below seed	600	226	131	357±38	23	490	253	69	812±19	98
Bands 3.5 inches to each side, 2 inches below seed	600	257	134	391±31	43	569	243	45	857±23	100
Mixed with soil below seed	600	240	107	347±36	20	493	227	52	772±23	98

EFFECT OF PLACEMENT OF FERTILIZER

On the Norfolk very fine sandy loam and the coarse sand highest yields were obtained where the fertilizer was placed to the sides of the seed and where it was placed in a band 3 or more inches below the seed. (Table 12.) The side placement was slightly superior. There is some indication that fertilizer placed in bands at the sides of the seed should be 2 or 3 inches below the level of the seed. The lower yields in all cases accompanied poorer stands. On the Cecil sandy clay loam, where good stands were obtained in all cases except where the fertilizer was applied in contact with the seed, highest yields were obtained with the shallower placements. On this heavy soil fertilizer applied in bands below the seed resulted in higher yields than fertilizer applied in bands at each side of the seed. Mature cotton plants fertilized with 800 pounds per acre of 4–8–4 fertilizer in a 1.75-inch band at various depths below the seed are shown in Figures 13, 14, and 15.

Applying one-eighth or one-fourth of the total fertilizer in contact with the seed and the remainder either in bands 2 or 3 inches below the seed or in bands 3.5 inches to each side of the seed usually resulted in reduced yields as compared to yields obtained where all of the fertilizer was applied in the corresponding placements some distance from the seed. On the Norfolk coarse sand some increase in yield was obtained where one-eighth of the fertilizer was applied in contact with the seed, but application of one-fourth of the total fertilizer in contact with the seed resulted in reduced yield.

On the average mixing the fertilizer with the soil produced yields approximately the same as the unfertilized checks. One of the advantages of applying fertilizer at the sides of the seed is that the seed may be planted in firm soil. Reduction in yield followed where the band of soil below the seed, which normally would be undisturbed when fertilizer is applied at the sides of the seed, was stirred just before the seed were planted. Some increase in yield was obtained where the seed were pressed in the furrow and covered with loose soil.

EFFECT OF RATE OF APPLICATION OF FERTILIZER

The application of 8–16–8 fertilizer at 200, 400, and 600 pounds per acre, as shown in Table 13, gave the highest yield for each rate

FIGURE 13.—Mature cotton plants on Norfolk very fine sandy loam fertilized with 800 pounds per acre of 4–8–4 mixture applied in a 1.75-inch band: *a*, 4 inches below the seed; *b*, no fertilizer; *c*, 3 inches below the seed; *d*, 2 inches below the seed. Photographed September 16

on the sandy clay loam soil when the fertilizer was placed 3.5 inches to each side of and 2 inches below the level of the seed. The same was true on the sandy soils for 400 and 600 pounds per acre, but at

FIGURE 14.—Mature cotton plants on Norfolk coarse sand fertilized with 800 pounds per acre of 4–8–4 mixture applied in a 1.75-inch band: *a*, 4 inches below the seed; *b*, 3 inches below the seed; *c*, 2 inches below the seed (seed pressed into furrow and covered with loose soil); *d*, 2 inches below seed (normal planting); *e*, 1 inch below seed; *f*, no fertilizer. Photographed September 13

200 pounds per acre on the sandy soils, mixing the fertilizer with the soil was slightly superior to, and the 1.75-inch band 2 inches below the seed was equally as good as, the side placement.

Failure to secure full benefit from increased rate of application of fertilizer through method of application is indicated in Table 13. On the sandy soils increasing the rate of application of 8–16–8 fertilizer from 200 to 400 and 600 pounds per acre resulted in reduced yields where the fertilizer was applied in bands 1.75 inches wide and 2 inches below the seed or where the fertilizer was mixed with the soil. Poor stands with the higher rates of fertilization where these placements were used was the principal cause of the reduced yields. Where the fertilizer was applied in bands at the sides of the seed, increasing the rate to 400 pounds per acre resulted in increased yield, but further increase in rate of application gave no further increase in yield.

FIGURE 15.—Mature cotton plants on Cecil sandy clay loam fertilized with 800 pounds per acre of 4–8–4 mixture applied in a 1.75-inch band: *a*, 3 inches below the seed; *b*, no fertilizer; *c*, 2 inches below the seed; *d*, 1 inch below the seed; *e*, in contact with seed. Photographed September 9

SINGLE VERSUS DOUBLE-STRENGTH FERTILIZERS

Yields (Tables 12 and 13) obtained with corresponding placements where 800 pounds per acre of 4–8–4 and 400 pounds per acre of 8–16–8 fertilizer were used showed no significant differences.

SUMMARY

This circular is the third of a series of reports presenting results of studies on methods of applying fertilizers to cotton in South Carolina.

Under the conditions prevailing in 1931, applications of 800 pounds per acre of 4–8–4 fertilizer drilled either in bands 1.5 or more inches to each side or 4 inches directly below the seed had no apparent injurious effects on germination.

On Cecil sandy clay loam appearance of seedlings was greatly delayed and the final stand was seriously reduced only when all the fertilizer was placed in contact with the seed, but on Norfolk coarse sand and Norfolk very fine sandy loam this occurred also when the fertilizer was placed below the seed either in bands at depths of 3 inches or less or when mixed with the soil and when one-eighth or one-fourth of the fertilizer was placed in contact with the seed.

Movements of soluble salts in the sandy soils from the original position of the fertilizer into the seed zone during the germination period were insignificant from placements at the sides but serious from placements directly below the seed. The degree of delay or injury to germination bore a close relationship to the amount of soluble salt carried into contact with the seed.

Seedlings came up most rapidly when the method of application produced a soil solution in contact with the seed containing between 0.05 and 0.2 per cent of soluble salts. As the concentration was increased from 1 to 3 per cent, fewer and fewer plants came up, and when the solution contained 3 per cent or more no plants came up.

The distance to which soluble salts spread from the point of application was greater in the coarse sand than in the sandy clay loam.

The highest yields were obtained with side placements on the sandy soils, but on the clay loam with heavy rainfall during the germination period the highest yields were obtained with bands placed 1 inch below the seed, although good yields were also produced in this soil with side placements.

There was no advantage either in mixing the normal amount of fertilizer with the soil as was done in these tests or in placing one-eighth or one-fourth of the application in contact with the seed and the remainder at the sides or below the seed.

Equivalent amounts of the 4–8–4 and 8–16–8 fertilizers produced similar results.

On the sandy clay loam where the final stand was good, increasing the rate of application of the 8–16–8 fertilizer from 200 to 400 and 600 pounds per acre gave increased yields for the three representative placements, but on the very fine sandy loam and coarse sand increased yields were obtained only when the fertilizer was placed in bands 3.5 inches to each side and 2 inches below the level of the seed. On sandy soils, when the fertilizer was placed below the seed or mixed with the soil the resulting reduction of stand gave lower yields.

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